Entered as second class matter at the New York, N. Y. Post Office, November 26th, 1890.

VOLUME IX.
NUMBER 3.

[COPYRIGHT, 1892.]

MARCH, 1892.

Annual Subscription $5.00
Single Copies - 50 cts.

TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.

REGULAR MEETING, MARCH 15TH, 1892.

Lightning Arresters and the Discovery of Non-Arcing Metals.

BY ALEXANDER J. WURTS.

PUBLISHED MONTHLY BY THE INSTITUTE, UNDER THE SUPERVISION OF THE EDITING COMMITTEE.

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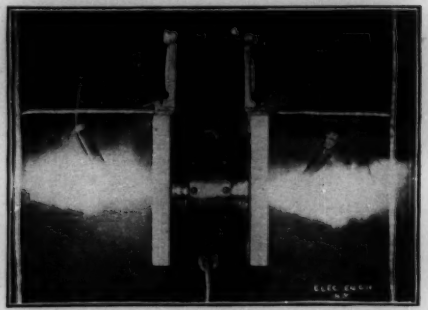
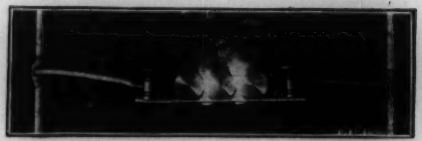
[March 15, 1892.]

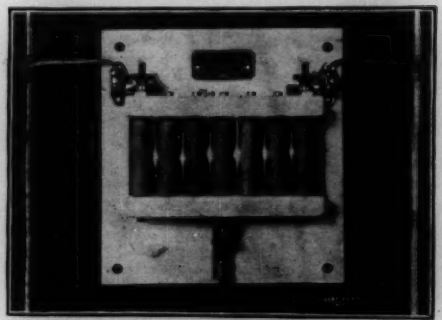
Photographs illustrating 1,000 volt short-circuits, and the different effects obtained with arcing and non-arcing metal electrodes, and with large and small air-gaps.



Automatic Air Blast Double Pole Lightning Arrester. This arrester was first exposed with the electrodes fixed in the position shown, and the flash taken subsequently.

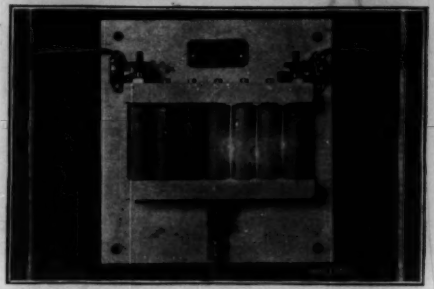


Interruption of short-circuit between non-arcing metal electrodes, with two $\frac{1}{16}$″ air-gaps.

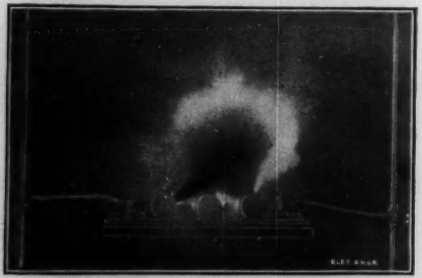


Double Pole Non-arcing Metal Lightning Arrester. Interruptions of short-circuit between poles, $\frac{1}{32}$″ air-gap.

Short-circuit maintained between non-arcing electrodes, with two $\frac{5}{8}$" air-gaps.



Double Pole Non-arcing Metal Lightning Arrester. Interruption of short-circuit between Line and Ground.



Short-circuit maintained between non-arcing electrodes, with two $\frac{5}{8}$" air-gaps same conditions as above.

1,000 volt short-circuit maintained between copper electrodes (arcing metal), with two $\frac{1}{32}$" air-gaps.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

New York, March 15th, 1892.

The Sixty-fifth meeting of the American Institute of Electrical Engineers, was held this date at No. 12 West Thirty-first Street. The meeting was called to order by Vice-president Thomas D. Lockwood, who said,

Gentlemen: Recently looking over the proceedings of a British institution, I found the following statement made by a well known man; that about 150 years ago, Franklin made the first useful application of electricity. When one considers the subject, it seems rather odd to regard a rod devised to prevent the destructive effects of electricity, as being a useful application of the agent it is intended to counteract. However that may be, I am very glad to have the opportunity of introducing to you one who has done his best to follow up the same line of work as was initiated by Franklin. I have much pleasure in introducing Mr. Alexander J. Wurts, who will read his paper on Lightning Arresters and the Discovery of Non-Arcing Metals.

[Mr. Wurts read the following paper.]

A paper read at the 65th Meeting of the American Institute of Electrical Engineers, New York, March 15th, 1892, Vice-President Lockwood in the Chair.

LIGHTNING ARRESTERS, AND THE DISCOVERY OF NON-ARCING METALS.

BY ALEXANDER J. WURTS.

During thunder-storms electric wires become charged from the atmosphere with an electric potential, different from that of the earth; there is then a tendency to establish an equilibrium, that is, for a discharge to or from the earth as the case may be. If this discharge be left to choose its own path, it will select one or many of the weaker points, usually the most vital part of the system, and there rupture the insulation. It therefore becomes necessary to rid the line of this charge in some suitable manner, and without allowing it to damage any portion of the system. This is usually accomplished by the well-known air-gap lightning arrester. Benjamin Franklin nearly one hundred and fifty years ago, drew sparks across an air gap from a charged conductor very much as we do it to-day. He, however, did this to demonstrate the presence of the charge, while we do it for good riddance.

Shortly after the erection of the first telegraph line by Morse in 1844, it was found necessary to provide means for discharging the line during thunder-storms, and numerous devices were brought out and patented for this purpose. The main features of lightning arresters from that time till recently have been the "spark gap" and the "kicking coil," the latter being interposed between the discharge circuit and the apparatus to be protected. The spark gap arrester on telegraph lines answers the purpose admirably as far as lighting and atmospheric induced charges are concerned. When, however, electric lighting was introduced, the lightning arrester problem became more difficult in consequence of the dynamo short-circuit that invariably follows the discharge. It then became necessary to provide means for

promptly interrupting this short-circuit, and so the fuse was added, and then there followed all kinds of automatic devices for interrupting the short-circuit and restoring the arrester to its normal condition. But most of these devices have been more or less defective and unsatisfactory, and now that high potentials are used, the proper interruption of the short-circuit becomes more difficult than ever. A very interesting method of interrupting the electric arc, is that which is commonly called the "magnetic blow out." The action of a magnet upon the voltaic arc was first observed by Davy, and afterwards carefully studied by De la Rive, who, in describing the various phenomena connected with this subject, mentions the fact that an electric arc cannot be

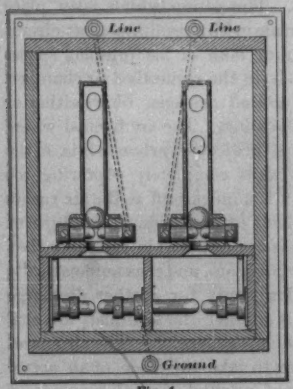


Fig. 1.

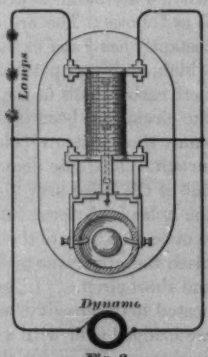


Fig. 2.

maintained between two points when placed in a strong magnetic field. M. De la Rive's researches on the voltaic arc were published in the Philosophical Transactions, Vol. 137, 1847. The ideal lightning arrester would be a simple discharge gap of such a character as not to permit a short-circuit of the dynamo, or better yet, metallic connections to the ground without dynamo leakage.

When I first became interested in this subject, I was naturally guided somewhat by previous practice, which had been to provide with each arrester and discharge circuit, an automatic circuit interrupter. Fig. 1 illustrates my first practical step in this direction, and represents the Winsor-Wurts lightning arrester, the fundamental idea of which emanated from Mr. Paul Winsor,

who proposed that a discharge gap be placed in the neck of a bottle, the idea being that the heat of the arc formed by the short-circuit would sufficiently expand the air in the body of the bottle to blow out the arc. With this idea as a nucleus, the arrester depicted in Fig. 1 was evolved. Referring to the figure, it will be noticed, without going into detail, that the arrester is double-pole and that each discharge gap is placed in the centre of an air chamber. In the upper part of each of these there is a slotted passage, which might correspond to the neck of a bottle, and in which there is placed a second air-gap in series with each of the others. The second air-gap is bridged with a carbon ball, the latter being held in place by tubes having vent holes in the sides and rubber bumpers at the top. The action which takes place when a discharge to ground is made with a resulting short-circuit is as follows: The arc at either or both of the jumping spaces instantly heats and expands the air in the respective air chamber, which, rushing up through the slotted passages, blows either or both carbon balls to the top of the tubes. The arc formed where the circuit has been broken by the projected carbon ball is, at the same time instantly blown out, thus completely rupturing the circuit. The only demonstration is a quick puff as the air rushes out of the holes near the upper ends of the tubes. The object of the holes is obvious. As the balls are confined in the tubes they at once drop back to their former positions, and thus automatically place the apparatus in a condition ready for another discharge and short-circuit. In testing this arrester the terminals are connected to the circuit of a thousand-volt generator. The air spaces are bridged ever with a fine wire to take the place of an actual discharge. Then, by the throw of a switch the full pressure of the machine is placed on the arrester. There is an enormous rush of current, the temporary wire bridges fuse, arcs are formed, the air expands with an explosion, the balls fly up, more arcs are formed, tongues of fire shoot out of the holes in the tubes, the upper arcs are blown out, the balls drop back to their normal positions, and all this happens like a pistol shot, without causing more than insignificant flicker in the lamps. It is very curious to notice that if this short-circuit is made, as I suppose it often is, on the crest of a wave of an alternating current, the report of the explosion is much sharper and louder than when the circuit is closed at the instant the wave is at or near the neutral point. I might add here, that, after short-circuiting a thousand-volt 3,000

light machine through such an arrester about 400 times, there was not the slightest deterioration to be noticed anywhere. Those who are not familiar with this kind of work will hardly appreciate this last fact, or realize what is accomplished each time the arrester "goes off."

Soon after this arrester was completed, steps were taken to adapt the same principle to an arc circuit lightning arrester, which resulted in the one illustrated in Fig. 2. By referring to the figure, you will notice that a vertical solenoid provided with an iron core is connected in the main circuit beyond the point of contact with the discharge circuit. The discharge electrodes are curved arms which swing freely through the sides of a cylindrical

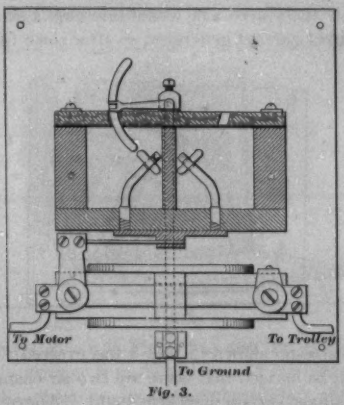


Fig. 3.

air chamber, and the construction is such that when the core falls, the discharge electrodes will be forced out. The action is then as follows: Under normal running conditions the core is held up in the solenoid, but if a discharge occurs from both sides at once short-circuiting the machine through the discharge points, the solenoid will at once lose its power, the core will fall and force the discharge arms out through the holes in the walls of the chamber. This action would draw out arcs three inches long, and the heat thus generated is sufficient to cause a sudden expansion of air in the air chamber and thus blow out the arcs even though the current be but ten amperes and the pressure 3,000

volts. Without the device just described for lengthening the arc, the heat developed would have been insufficient. In short-circuiting a 50-light machine through this arrester, there is a scarcely perceptible flicker in the lamps, the core drops, the short-circuit is opened and the core drawn back into its normal position ready for further action, all in an instant of time. Although I have used an electromagnetic device in the construction of this type of arrester, it will be noticed that the placing of a coil in the lightning arrester circuit has been avoided, so that even though every discharge has to pass through this coil to reach the discharge points, yet from this point on, the discharge has a non-inductive path to earth through the arrester in preference to the dynamo.

Neither of these arresters would interrupt a short-circuit on a 500-volt direct current generator, so after some further experi-

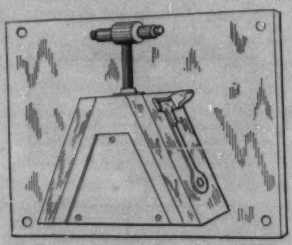


Fig. 4.

menting the arrester shown in Fig. 3 was evolved. Referring to Fig. 3, it will be noticed that there are two air chambers, in each of which is a fixed carbon discharge point. Above these chambers is a curved carbon swinging freely from one chamber to the other through suitable openings, so that either end of the curved carbon, as the case may be, shall come into close proximity to either of the fixed discharge points. The action is as follows: When a discharge takes place, it passes to one of the fixed discharge points, depending upon the position of the curved carbon, then across the air space to the curved carbon, and from there to the ground as shown in the figure. The dynamo current then following, causes an arc to be established between the curved carbon and one of the fixed points, and the heat generated by this arc expands the air in its respective chamber, increasing the

pressure therein, and causing the curved carbon to be instantly blown from one chamber to the other. This ruptures the arc and adjusts the arrester for the next discharge. In testing this arrester, 500-volt and 1,000-volt generators have been repeatedly short-circuited through it, and in every case the circuit has been instantly broken without injury to the dynamo, and the arrester has as quickly reset itself in readiness for future use. In one of the tests made to demonstrate its promptness and reliability, the fixed points were so adjusted as to touch the curved carbon in either of its two normal positions. A 1,000-volt generator was then short-circuited through the arrester, which resulted in the circuit being repeatedly opened and closed without injury to either dynamo or arrester. This power circuit arrester was afterwards much improved, and finally took the form shown in Fig. 4,

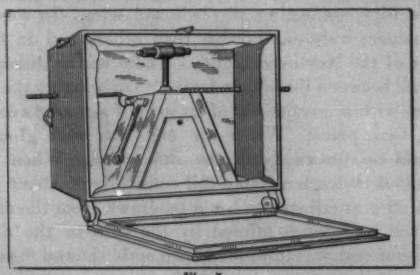


Fig. 5.

and the arrester shown in Fig. 1 was also finally changed to this form. This arrester is made of iron and marble, and its advantages over the others are its non-combustibility and the double break in connection with the air blast. Fig. 5 illustrates the same arrester, fitted into an iron box lined with asbestos, and in this shape is adapted to either car or pole use.

So far you will observe that my one object had been to provide a simple, reliable and non-inductive circuit interrupter. In this I had succeeded as far as immediate wants were concerned, but with the prospects of higher voltages in the near future the problem seemed but imperfectly solved. The experiments of Lodge, Hughes, and others were carefully studied, and I finally decided that it might be well to repeat some of them. So, one day, while casting about for some suitable means of experiment-

ing, I happened to be passing under a driving belt; my hair stood on end, and my body became charged. Of course somebody had to touch my ear (that seems to be the proper thing to do under the circumstances), and my body became discharged. That evening while thinking over the events of the day, my thoughts rested on this belt, the electrified atmosphere around it, and the charging and discharging of my body, and I wondered whether the phenomena observed were not very similar to those experienced during thunder storms. On the following day I stretched about four feet of No. 14 insulated wire under a belt, parallel to it, and about two inches below it. I then brought the ends to a convenient place where I could ground the wire or not as I chose. The room was then darkened, the belt set in motion, and a most beautiful sight presented itself. Between the belt and the wire were seen soft purple streamers, giving the appearance of a film connecting the belt and wire. In some places these streamers were more dense than others, and in this were suggestive of the Northern Lights. There was no disruptive discharge at all between the belt and wire. On bringing the bare end of the wire within one quarter of an inch of a ground a continuous discharge took place. When one end was well grounded no spark could be drawn from the other end. When one end was grounded through a choke coil consisting of about 40 turns of No. 14 wire, small sparks could be drawn from the other end, showing the impedance offered by the coils to the discharge. When neither end was grounded both ends showed "side flash" every two or three seconds. So far, these results seemed to correspond with the experience met with in electric systems when exposed to the influence of thunder-storms. The conditions also seemed to be very similar. Here was a wire stretched through an electrically disturbed atmosphere; the wire became charged, and the charge passed readily to ground through a metallic discharge circuit containing an air-gap. An induction coil impeded the discharge, and when there was no ground connection there was side flash. All these results seemed to correspond with practice.

The thought then occurred to me, "What would happen if I were to string a second wire near and parallel to the first, and ground it, leaving the first wire insulated?" A second wire was quickly strung, but before making the ground connection the following observations were made. The purple streamers seemed

equally divided between the first and second wires, and either would give about equal sparks. On grounding the second wire no indication of a charge on the other could be obtained. The streamers were now all directed to the second wire, and the first was as inert as a block of stone would have been. If, now, in these laboratory experiments, there were reproduced the conditions existing between electric wires and the atmosphere during thunder-storms, then, to prevent wires from becoming charged, all that would be necessary would be to stretch a grounded wire near and parallel with the wire to be protected, and, in fact, it would seem as though one such grounded wire would protect all the wires that could be strung on any one line of poles. An explanation of these phenomena is not far to seek. An insulated wire lying on the surface of the earth cannot become charged from the atmosphere, because the latter is at the same potential as the earth; but an insulated pole line can be, and is charged

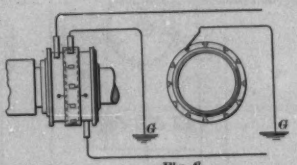


Fig. 6.

when exposed to the influence of thunder-storms, because the atmosphere surrounding the wire is at a different potential from the earth; therefore with an insulated pole line, and an adjacent grounded parallel wire, the grounded wire in effect transfers the earth to the level of such wires, but if a grounded wire near and parallel to an insulated wire in effect causes the earth to be transferred to the level of the insulated wire, then the insulated wire cannot become charged. The grounded wire running over the poles will relieve the atmosphere in its neighborhood of any difference of electric potential that would otherwise exist between that neighboring atmosphere and the earth, and the insulated line would then fail to become charged. Soon after performing this experiment, I learned that such an overhead grounded wire had been used to great advantage, and that being the case was greatly surprised that it was not in more general use.

I next replaced the wire I was using, which was much battered and bruised, with a new wire, and found the charge much dimin-

ished by the superior insulation. The latter was then replaced by bare wire insulated with a glass tube. The spark now was scarcely perceptible, being about the size of the spark obtained from a Leclanche cell, and even this could be obtained only after several minutes of charging. These results seemed to indicate a gradual charging of the wire by more or less perfect contact with an atmosphere having a different potential from that of the earth. With the idea of gradual charging in mind, the following plan was hit upon for a lightning arrester. The first conception was to alternately ground both poles of a generator over a very small air-gap, and at rapidly recurring intervals. The improved plan, however, was to alternately dead ground the poles of an alternator at every neutral point in the electromotive force wave, the

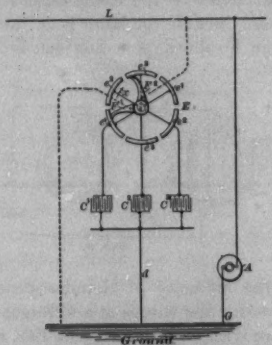


Fig. 7.

idea being to so constantly discharge the line in this manner, as to effectually prevent a charge from attaining any considerable intensity, and at the same time avoid the short-circuit which now invariably follows the discharge over the air-gap of our present arresters. The method of carrying out this plan will be understood by a glance at Fig. 6, which represents an elevation and end view of the collector rings of an alternator, also the ground brush which alternately grounds the poles of the generator at every neutral point in the E. M. F. wave. Upon experimenting, I found that an alternator could be short-circuited at the neutral point without a spark. If the short-circuit occurred a little before the neutral point, that is, on a decreasing electromotive force, there was slight

sparking, but no tendency to hold on. If the short-circuit occurred at all after the neutral point, a furious arc was established which would hold on indefinitely.

This form of arrester has not yet been tested in actual practice, but it will be during the coming season, and I have great hopes that it will not only successfully discharge the line, but effectually prevent any considerable accumulation of the charge. Of course this form of arrester is only adapted to alternators.

For direct current use I have devised something quite similar, the principle of which will be understood by reference to Fig. 7. Referring to the figure, A is a generator, one pole of which is grounded at G, the other being connected to the trolley line L; E is a circuit controlling device consisting of fixed commutator like metal pieces e^1, e^2, e^3, opposite pieces being electrically connected; F^1, F^2, are brushes insulated from each other and revolving at a

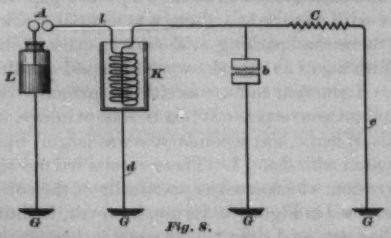


Fig. 8.

high speed in a direction indicated by the arrow, F^1 is connected to earth, and F^2 to the line: e^1, e^2, e^3, are connected respectively to three condensers, c^1, c^2, c^3, the latter being grounded as indicated at *d*. The action is as follows:—With the brushes in their present positions, the line is connected through F^2 and e^3 to condenser c^3. This condenser is therefore being charged while condenser c^1 is being discharged to earth through e^1 F^1. When F^2 passes to e^1, condenser c^1 will be connected to the line, and become charged while condenser c^3 will be discharging through e^2 and F^1. Thus by the continued rotation of these two brushes, it will be seen that the trolley line is being constantly discharged into a fresh condenser.

This arrester has also not been tested in actual practice, but if my hopes are fulfilled it will accomplish for direct current circuits what the neutral point arrester is intended to accomplish for

alternating circuits, the idea being in either case to take off the charge bit by bit, but at such rapidly recurring intervals that the line will be kept practically free from charge, or, at least prevent the charge from attaining sufficient intensity to damage any portion of the system. Personally I am much interested in these two arresters, which practically afford direct connection to earth without dynamo leakage, and would like to dwell on them more in detail, but time will not permit.

Referring once more to my experiments with charged wires, I would say that they were nearly all repetitions of experiments quite familiar to all of you. Let me, however, call your attention to one of them which I am confident is not old in detail. Referring to Fig. 8, L is a Leyden jar, *l* is a bare line wire, a portion of which is coiled and immersed in a tank K of water. This tank is well grounded. Line *l* is continued through induction coil C and then grounded as shown; *b* is a gap discharge circuit. Now with a spark at A there was a small spark at *b*; with a gap at *d* there was sparking at *d* and *b*, spark *d* being larger than *b*. With a gap at *e* sparks were obtained simultaneously at *d*, *b*, and *e*. Induction coil C was either a primary or a secondary of a 40-light converter. When C was primary, spark *e* was very small. When C was secondary, *e* was larger, but still small when compared with *d* and *b*. These results led me to what I call the tank arrester, which consists practically of the coil and tank of water represented in Figure 8. Its use, however, is limited to comparatively low potential circuits. In practice I propose to immerse in a tank of well grounded running water a coil consisting of about fifteen feet of No. 0000 bare wire, and connect this coil in series with the trolley circuit. The apparatus as I have designed it will give a leakage current of 3.7 amperes at 500 volts, which, however, is inconsiderable if adequate protection is provided. Of course with suitable means for cutting out this arrester, the leakage need only occur during stormy weather. The prominent features of this arrester are: First, the comparatively large portion of the line exposed to ground connection; second, the opportunity for constant leakage of the charge, that is, the intensity of the charge need not rise to the striking electromotive force of an air gap before beginning to discharge; third, the fact that whatever charge may be induced on the line will be forced to pass through this tank before reaching the generator; and fourth, the impedance of the coil, which will tend to force

the charge from every point on its surface into the water and therefore to earth.

From my experience with charged wires I learned two lessons, both of them old, but in books they had not impressed me as they did in practice. The first lesson was, that I must not expect one or two discharge circuits to discharge the many miles of wire that we have in our lighting and power circuits. The second was that a "kicking coil," no matter how great its impedance, would still take a portion of the discharge. My final conclusions then were; that in order to afford the best possible protection for electric plants, the wires must fairly bristle with discharge points properly located in discharge circuits. With this idea in mind a cheap and effective pole arrester seemed to be the proper thing to look for. My experiments from this time on led me to a discovery so remarkable, and so contrary to all previous ideas, that I am going to read you a description of them.

In designing the arresters already described, I had followed closely the rut of previous practice, which had always been to provide with each discharge circuit, a circuit interrupting device. Upon reflection, however, it was evident that one circuit interrupter placed in the main circuit would interrupt the arc on any discharge circuit. For a moment the problem of a simple pole arrester seemed solved, but on second thought the difficulties and inconveniences inseparable from any automatic main circuit interrupter appeared to be insurmountable, and the idea was no sooner conceived than it was abandoned. And yet, poor as it was for practical purposes, it proved a good stepping stone, and led to the following plan, viz.: To provide the line with ordinary discharge circuits, that is, with the well known saw-tooth protectors, made of carbon so that they would not easily burn away; and then in the station, between the generator and the first discharge circuit, provide an automatic device which, upon the passage of an abnormal current from the generator, would instantly short-circuit the dynamo and as quickly open again, the intention being that should a short-circuit occur out on the line through any of the discharge circuits, a short-circuit at the dynamo would so reduce the pressure on the line as to render it impossible for an arc to maintain itself. Then, any such arc having been extinguished, the short-circuit at the generator could be interrupted, and the service would continue as before. This idea meeting with general approval, steps were at once taken to

put it to a test in the following manner: To a 1,000-volt alternator there was connected a circuit consisting of about 100 yards of line wire, and in this circuit there was placed a pair of carbon dischargers having saw-tooth edges, and a $\frac{1}{16}$ in. air-gap, also a switch. In shunt with this circuit, that is, directly across the terminals of the generator, there was connected a simple device (it will not be necessary to explain its construction) which, upon the passage of an abnormal current in the circuit containing the dischargers, would instantly short-circuit the generator and as quickly open again. All the connections being made, the air-gap was bridged with a bit of tinfoil to start the arc, and the switch thrown. The actions that followed in an inconceivably short space of time were these:—The tinfoil burst with a snap, an arc was formed, the automatic short-circuiting device operated, the arc was extinguished and the short-circuiting device opened. So far, this was exactly what was anticipated, but no sooner had the short-circuiting device opened, and the electromotive force returned to the line and the dischargers, than the dynamo pressure forced an arc across the air-gap once more, and the whole operation was repeated. This repetition was found to be due to the fact that when the arc was first established between the carbon saw-tooth plates, the carbons were heated to a white heat which not having time to dissipate itself before the pressure returned, the dynamo current found a sufficiently easy path over the heated air-gap to re-establish an arc. However, the test being otherwise satisfactory, success seemed assured, for all that was necessary now was to use solid metal dischargers that would readily conduct the heat away, and the trouble above cited would no doubt be avoided. So the test was repeated, using the same apparatus as before, except the dischargers, which now consisted of three solid, round, brass rods, 1 in. in diameter and $1\frac{1}{4}$ in. long, placed side by side with their axes parallel to each other, and having air gaps of $\frac{1}{16}$ in. That is, the line was connected to the two outside bars, leaving the middle one idle to be connected to ground, as would be the case in a double pole lightning arrester. The air-gaps were bridged as before with tinfoil to start the arc, and the switch thrown. The test was successful in the highest degree—too successful, in fact, not to arouse suspicion. So I thought I would repeat the experiment, and see how the dischargers would behave without the short-circuiting device. The result was an overwhelming surprise, for at the dischargers there was merely an insignificant spark scarcely larger than a pea. The experi-

ment was tried again and again, with the same result. Any electrician would have predicted a brilliant display of fireworks. The most plausible theory advanced to explain this action was that the electric motor driving the dynamo being small, its speed was probably reduced to such an extent by the overload suddenly thrown upon it, that the electric pressure was at once reduced below that which would be necessary to maintain an arc across the air-gaps. On second thought, this theory would have seemed improbable, but at the time it was accepted without a question. In a few days a test was again made, this time a small engine being used for motive power, and the same results were obtained as before. The afternoon of the same day both engine and generator were changed, with like results. In the meantime a little reflection seemed to indicate that perhaps this strange action was not, after all, due to the slowing down of the motor, but to the possible cooling effect of the metal dischargers on the arc. With this idea in mind, I had constructed, a set of three dischargers similar to the first, but much larger, $2\frac{1}{2}''$ diameter x $3''$ long, thinking that if a little metal was good, more would be better, and that perhaps with a large generator the mass of metal would have to be greatly increased to produce the results already obtained. This large discharger was connected to a 3,000-light, 1000-volt alternator; the air spaces were bridged as before; and the scene which followed beggars discription. The large metal bars were melted like beeswax in a great ball of fire. My disappointment was keen for I thought I was on the verge of making a discovery, and that in the previous cases the comparatively feeble engine had not been the cause of the action. Thinking, however, there could be no harm in melting up the smaller discharger, I connected it in where the larger one had been, bridged the air space, and threw in the switch. Imagine my astonishment on hearing an insignificant snap like the crack of a toy pistol, and seeing an arc as before no larger than a pea. I then pushed a nickel down into one of the air-gaps to short-circuit it, and leaving only one air-gap for the arc, and tested again, with the same results. Two questions now presented themselves: viz., what were the differences between the large and small dischargers other than size, and why did the small discharger behave in this altogether unlooked for manner? The answer to the first question was readily found by tracing the two dischargers back to their source, and there learning that the larger one of the two was made of cast brass, containing certain

proportions of tin and copper, and that the smaller one was made of hard-drawn brass, containing certain proportions of zinc and copper. These facts at once established two differences between the dischargers other than mere size; one was, their physical structure, the other their composition. Which of these two differences caused the difference in their actions? A discharger composed of cast brass containing the same proportions of zinc and copper as the hard-drawn brass discharger was made and tested, and found to work perfectly. It was thus determined that the physical structure of the metal had no influence in suppressing the arc. The important difference between the two dischargers then lay probably in their composition, and I was now rapidly becoming convinced that in brass, consisting of certain proportions of copper and zinc, there must exist certain properties which do not permit of an arc being maintained between two dischargers, even with the high pressures of 1,000 volts. It also occurred to me that possibly the shape of the dischargers had something to do with the results obtained. So the next step taken was to have a number of dischargers made up in different shapes and sizes, such as spheres, ovals, solid half cylinders, tubes and cubes; all worked well with the exception of the cubes. The cubes were placed so that their faces were separated by $\frac{1}{16}''$. Now when the tinfoil was placed over their edges, the action was favorable, but if the tinfoil were pushed down between the faces, the arc would hold on indefinitely, and yet without any demonstration whatever, thus, even when the arc did hold on, showing a very different action from the other metals. The size of the dischargers did not seem to affect the results so long as there was sufficient metal to prevent actual melting—$\frac{1}{4}$ in. brass rod melted on the third trial. It was next decided to make dischargers of other metals, and thus learn whether there were any other substances that would give these results, and if so, perhaps some light would be thrown on the real cause of the action. The metals first tested were hard steel, hard-drawn copper, phosphor-bronze, aluminium-bronze, and aluminium, all of which failed utterly. The next metal tested was zinc, and with this, most successful results were obtained. Perhaps you will now think the experimenter very slow to put two and two together, but who is there who is at all familiar with the properties of zinc, that would have suggested this metal as one likely to resist an electric arc and 1,000 volts in this manner? With such results before me, I was ready to try anything. The next metals were tin and nickel. Both of

these failed. Tin made the most brilliant display of all the metals. The next tried was antimony, and it worked perfectly. The theory now advanced to explain the phenomena was that with the metals that do not allow the arc to be maintained, there is formed at the instant the arc is started, an oxide of the metal which, becoming instantly volatilized in the intense heat of the arc, chokes up the air-gap with vapors of high resistance, and so presents an effective barrier to the further passage of the current. With metals that do maintain the arc, instead of the vapor of the oxide of the metal, there is formed a pure vapor of the metal itself, and this offers comparatively no resistance to the passage of the current. When tests similar to the above were made on a 500-volt direct current generator, every one of the metals failed. The arc, however, was small and quiet with the special metals, thus even with the direct current showing a very peculiar action. Another curious phenomenon connected with zinc and antimony is this: The smaller the air-gap the less tendency there is to maintain an arc when using an alternating current at 1,000 volts pressure. In fact, when the air-gap is two inches long the arc, when once started, will be maintained, while at $\frac{1}{2}$ in. or $\frac{1}{4}$ in. the arc will not give up without a struggle, and at $\frac{1}{10}$ in. there is only a small spark caused by the fusing of the tinfoil, and the circuit is instantly interrupted.

The next step taken was to try higher pressures. A short circuit on a 2,000-volt generator, through the double air-gap discharger, failed to be interrupted; four and five air spaces also failed. Six air spaces of $\frac{1}{10}$ in. each, interrupted the short-circuit instantly, but six air spaces, which would make three on each side of the circuit for the lightning charge to jump through, were strongly objected to as offering too great a resistance. A test was then made to determine the pressure needed to strike an arc across three air-gaps, and was found to be 3,500 volts, measured with a Cardew on an alternating current generator. The experimenter then procured a lightning arrester well known in the market, and one which is known to take the lightning discharge successfully, and tested it for the striking electromotive force, which was found to be between 8,000 and 9,000 volts. In order, however, to avoid any prejudice that a series of air-gaps might arouse, the following plan was hit upon: Pairs of non-arcing dischargers, Fig. 9, were mounted upon thermostatic supports in such a manner that the pairs would normally rest in contact with each other, and so that any current traversing the system would be forced to pass

through the thermostats and dischargers in series. The thermostats were so arranged as to cause the two dischargers in each pair to open a way from each other upon the passage of the current. If then, a single and permanent air-gap were connected in series with this system, that is, an air-gap just sufficient to prevent the normal pressure of the line from striking any arc, and if an arc were started across it, the sudden rush of current through the thermostats would instantly introduce a number of air-gaps in the circuit corresponding to the number of pairs of thermostatic dischargers, and thus automatically open the short-circuit. This

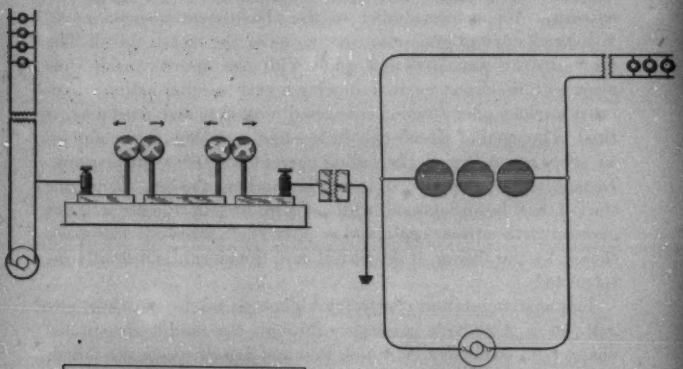


Fig. 9.

Fig. 10.

device was tested and found to work admirably. Of course after the circuit has been interrupted, the thermostatic dischargers at once return to their normal positions. In fact, this action is so rapid that if a series of these dischargers be connected in a short-circuit without a permanent air-gap, the circuit will be automatically opened and closed every two or three seconds. In order to appreciate the very remarkable action of this thermostatic device it must be well borne in mind that a very small air-gap is all that is necessary for the interruption of the circuit.

Thus far, although I had tested a number of metals, my selec-

tion had been quite at random, so that by this time I was desirous of making a more thorough and systematic investigation of this new property. The chemical properties of zinc, and antimony were carefully compared without any new light. The various groups of metals were examined, and then it occurred to me that, of all the metals tested, not one of them belonged to the two groups in which zinc and antimony are found, according to Mendelejeff's grouping. The metals of the zinc group are,—

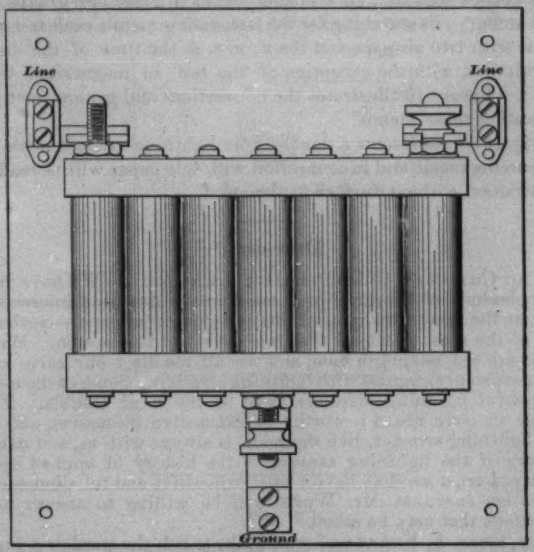


FIG. 11.

Zinc, cadmium, mercury and magnesium, and of the antimony group are,—antimony, bismuth, phosphorus, and arsenic. I first tested cadmium, and found it non-arcing. Then magnesium,—more, however, from a sense of duty than because I had hopes of anything but negative results. Fortunately I made this test on much lower E. M. F.'s, and found it non-arcing at 100 volts over two air-gaps of $\frac{1}{32}$ in. each. On 250 volts the magnesium caught fire, which was, of course anticipated. I then wanted to try mer-

cury, but for the moment, not seeing how to make such a test with a liquid, I was diverted to the antimony group, and upon testing bismuth found it to be non-arcing. Phosphorus and arsenic were not tested. A final attack was now made upon the zinc group by testing mercury in the form of a copper amalgam. This test was the most successful one of all, for after a number of short-circuits on a 1000-volt alternator, I found the surface of my dischargers had not been disturbed in the slightest degree. It will thus be seen that all available metals in these two groups are non-arcing. In searching for the non-arcing metals each test was made with two air-gaps and the E. M. F. at the time of the short-circuit was, with the exception of the test on magnesium, 1000 volts. Figure 10 illustrates the connections and general method of testing these metals.

Figure 11 represents a double pole lightning arrester made of non-arcing metal, and in connection with this paper will be readily understood without further explanation.

Discussion.[1]

The Chairman, [Vice-President Lockwood]:—We have had the pleasure of listening to a most instructive and interesting and, at the same time, a most intensely practical paper—perhaps one of the most practical that we have had this season. Many of us are old telegraph men, and we all recollect our early and our persistent struggles with lightning arresters. Some of the most successful lightning arresters gave us the most trouble. The paper we have heard is worthy of exhaustive discussion, and as the lightning arrester, like the poor, is always with us, and as the history of the lightning arrester is the history of applied electricity, I trust we shall have a most exhaustive and full discussion, and I am sure that Mr. Wurts will be willing to answer any questions that may be asked.

Dr. Chas. E. Emery:—I would like to ask the speaker a question with reference to the statement on page 15, that the tests failed for a direct current of 500 volts (that is practically the same as used on railroad work), whether or not this apparatus as finally constructed will protect direct current apparatus operating with high voltage.

Mr. Wurts:—This metal, which I have called "non-arcing," will not of itself interrupt direct current circuits from street car generators. This action, however, of the direct current on non-arcing metal is very peculiar, thus distinguishing it from other

1. By Messrs. Birdsall, Emery, Kennelly, Lockwood, Prescott, Sullivan, E. P. Thompson and Wetzler.

metals even though the arc be maintained. When short-circuiting a street car generator through these air-gaps, the arc is very small and quiet; but I have not been able to interrupt such circuits by the simple use of this metal. The arresters which have been described (Figs. 3, 4 and 5,) and which are on the floor, are used on direct current circuits. Fig. 4 illustrates the arrester used on 500 volt trolley circuits. These arms which are the discharge electrodes, fly out by the expansion of the air in this air chamber, and thus rupture the circuit, and the arms falling back to their normal position, instantly and automatically place the arrester in a proper condition to repeat the operation. In testing these arresters the arc is started by placing a bit of tinfoil in the

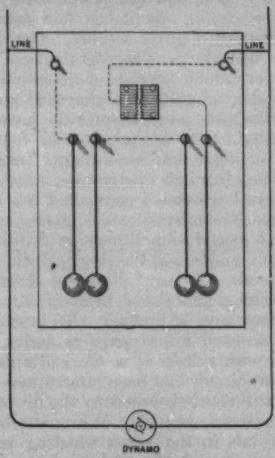


FIG. 12.

air-gap and the short-circuit is thus established on a large street car generator. This same arrester placed in an iron box, as illustrated in Fig. 5, is adapted to either car or pole use. Before this arrester was designed, the one shown in Fig. 3 was used. Here is a photograph of the flash as the arrester operates.

I have a curious device here, Fig. 12, but do not know that it has any practical value. You will notice that here are four brass posts extending horizontally from this back-board and from which are suspended, by means of copper ribbons, two pairs of non-arcing metal balls, the balls being about an inch in diameter. The two balls in each pair normally rest in contact with each other. Just above these you will notice an ordinary lightning

arrester discharge gap. Now the arrangement is such that the copper ribbons, the ball, and the discharge gap are connected in series with each other, so that if an arc be established across the air-gap, the current will follow down one copper ribbon to the metal ball, then across to the next ball, up that ribbon, across to the next ribbon, down and across the next two balls, and finally up the last copper ribbon. The action then with an alternating current is this: the amount of heat generated between the metal balls resting in contact with each other is sufficient to expand the air and thus force the balls apart, and as a very small air-gap is all that is necessary to interrupt the circuit when using a non-arcing metal, the circuit is instantly interrupted. This device, which I hold in my hand, has been tested a number of times on a thousand volt short-circuit, and if you will examine it, you will find the metal balls but slightly scarred. One very curious fact is, that the metal balls do not fuse together.

This sample here, which consists of three cylindrical rods, has undergone eight short-circuits on a thousand volt generator, and I have reversed the rods, so that you may see the action of the current on the metal. The scars cannot be felt with the hand, and each spot is no larger than an ordinary sized pinhead.

In short-circuiting through this sample, which is a commercial non-arcing lightning arrester. I connected the terminals of my generator to either of the outside bars, giving me three air-gaps, in each of which I placed a small piece of tinfoil not larger than the head of the pin, and closed the short-circuit, which was then instantly interrupted. On examining the air-gaps I found that only one of the bits of tinfoil had been fused. The tinfoils in the other two spaces were still intact. To interrupt a 3,000 volt short-circuit I connected ten air-gaps in series, short-circuiting each one of them with a drop of water, and upon examining the gaps after the short-circuit had been interrupted I found three or four of the gaps still short-circuited by the drops.

Mr. Geo. B. Prescott, Jr:—Mr. Wurts attributes the peculiar action of these metals to the non-conducting property of their vapor. I would like to ask him if he considered the possibility of its arising from a peculiar polarizing effect, due to the small air space and proximity and shape of the poles, on the molecules of the intervening atmosphere?

I came here to-night not expecting to hear very much that was new on a subject so old and apparently exhausted, but have been very agreeably disappointed. Mr. Howell's remark that it is a research, I think describes the paper.

The Chairman:—I think by an attentive reading of the paper it will be seen that Mr. Wurts ascribed the success of the non-arcing metals to the non-conducting vapor of an oxide which was formed there.

Mr. Wurts:—That is my present theory, that there is a non-conducting vapor formed in the air-gap which chokes the further

passage of the current. A fact which seems to lend strength to this theory is, that in order to obtain the non-arcing property, the air-gaps must be very small, and it seems as though under such circumstances the non-conducting vapors might be somewhat concentrated, but if the air-gaps be large, allowing plenty of fresh air to circulate, the vapors may be scattered, and thus allow the free passage of the current. I have also thought that perhaps there might be something in the nature of a counter-electromotive force hindering the passage of the current, or that perhaps the dischargers themselves were coated with a non-conducting film; but I do not think the latter is the case, as a bit of tinfoil dropped into the air-gaps will instantly re-establish the circuit. Of course this is only a theory that I have, and I am in hopes that some ideas will be brought out here which will aid me in further researches.

MR. JOSEPH WETZLER:—I would like to inquire of Mr. Wurts if he has ever considered the possibility of his non-arcing metal being used in the construction of safety fuses, as we might expect that if this metal were non-arcing, much of the danger now attending the maintenance of an arc when a fuse is blown would be obviated by using fuses of such non-arcing metals.

MR. WURTS:—I have some very interesting data on that point. As zinc is one of the non-arcing metals, I thought that if a zinc fuse were made, I would have one that would not establish an arc when "blown," but at that time I did not fully appreciate the necessity of a small air-gap for the immediate interruption of the circuit. I first made a fuse of pure zinc, and, upon short-circuiting, an arc was established very much as in the blowing of a lead fuse. I then made a fuse of about 50 per cent. zinc and 50 per cent. antimony, which, however, worked no better; but I have here a fuse block which permits of the use of lead fuses, and which when blown on a thousand volt short-circuit will not maintain an arc. You will notice that on this wooden block there are two sets of small non-arcing metal cylinders, there being three cylinders in each set. Over each set I stretched a lead fuse, and then connected the two fuses in series. In testing this fuse block on thousand volt short-circuits, I placed the block in a converter primary fuse box without lining; then when the fuses melted, the arc was instantly taken up by the small air-gaps between the non-arcing metal cylinders and a circuit immediately interrupted without the slightest tendency to flash to the walls of the iron chamber; in fact, the stumps of the lead fuse, you will notice are still in the block.

The fuse block that I now hold in my hand is the only one I have made for higher potentials, and you will notice that I have arranged seven non-arcing metal cylinders in the shape of a semi-circle, thus giving me six air-gaps, and over these I extend my fuse.

MR. WETZLER:—Of what metal is your fuse?

MR. WURTS:—I have used lead fuses, also copper and aluminium fuses. I connected the terminals of a self-regulating 2,000 volt alternator to the terminals of this fuse block and threw the switch, having first raised the E. M. F. of the generator to 2,500 volts. Please bear in mind that this was a self-regulating generator. The fuse was blown on the short-circuit and the arc immediately interrupted, whereas in short-circuiting through a similar fuse without the non-arcing metal cylinders, I was forced to separate the terminals of the fuse about a foot, before the arc would let go. This being the case it seems to me that this metal might properly be called "non-arcing." In testing without the metal cylinders, not only did I have to widely separate the terminals of the fuse, but I also passed the fuse, which was a copper wire, through a $\frac{1}{8}''$ hole in marble slabs, the slabs being placed next the fuse terminals for protection, thinking that in this way, I could bring the terminals of the fuse closer together, and at the same time extinguish the arc; but it was not until I had, even under these circumstances, separated the fuse terminals about a foot, that the arc would "let go."

MR. EDWARD P. THOMPSON:—In view of the great importance which the discovery of non-arcing metals by high potential alternating electric currents may have in other departments of the electrical industry besides that of lightning arresters, it becomes desirable, that every phase of the subject should become known. From the systematic manner in which Mr. Wurts has investigated the matter, I should judge that there is not one stone left unturned. I would ask therefore, as to any tests he may have made to show the necessary thickness the non-arcing metal should have in order to exhibit the peculiar property. For instance, suppose he employed as electric terminals, *arcing* metals such as copper, lead or any member of the same chemical class, coated each with a layer of *non-arcing* metal such as hard brass, zinc or mercury. The question is, how thick should the coating be, and what is the effect upon the metals?

MR. WURTS:—In answer to that question I will show you some copper amalgam dischargers which I made by electrolytically depositing copper into mercury. This process gave me a paste which I pressed into cylinders as you see, and then allowed to set. Mercury being one of the non-arcing metals the arc was not maintained. An amalgam, however, made in this manner is soft and readily crumbles away; but the amount of non-arcing metal that is necessary for instant interruption of the circuit is very small, and this fact is well illustrated by the following experiment:

I made three copper dischargers similar to those I have just shown you, and which I knew, under conditions of a short-circuit would maintain the arc. These discharges I first washed with acid and then dipped into mercury, thus slightly amalgamating the surface of the copper dischargers. The coating of mercury

was so thin that I could scrape it off with my penknife. I connected the terminals of the generator as before and caused eight short-circuits to be established one after the other across the air-gaps. The first time that I closed the short-circuit I did not notice a flash or any movement of the voltmeter and concluded that I must have had an open circuit, but upon examination found that the tinfoils had been fused. I presume I must have used exceedingly small pieces of tinfoil. I performed this experiment eight times, and then, upon examining the discharges, found them not to be burned or burred in the slightest degree, In fact I never would have known that they had been tested in this manner except for a little blackening caused by the fusing of the tinfoil. This form of non-arcing metal is, however, not practical, for upon repeating the test an indefinite number of times, the mercury was finally driven off, leaving the copper exposed and then the arc was maintained. So long, however as this thin film of mercury was present there was not the slightest tendency to arcing.

Dr. Wm. E. Geyer:—I should like to ask Mr. Wurts in those cases where the arc is not absolutely stopped but where the little arc is maintained, whether it keeps to one place or keeps running about between the rods?

Mr. Wurts:—The arc maintains a fixed position and is very quiet. On 3,000 volt short-circuits I have used six air spaces, which are not sufficient to interrupt the circuit and the arc was quietly maintained. There was no demonstration at all, but the current passing, judging from the temperature of the metal bars, must have been very great. The metal, however, does not burn even when the arc is maintained. When I say does not burn, I mean comparatively speaking, for after long continued arcing, the metal does show some signs of the arc.

Here is a single-pole line arrester consisting of four non-arcing metal cylinders and three air-gaps. I have used this in connection with high potentials, and have maintained the arc for one or two minutes at a time, and if you will examine it, you will notice that there is no roughening at all.

Here is a double pole line arrester which has seven non-arcing metal cylinders and six air-gaps, that is, three air-gaps from line to ground for the discharge to jump through. This arrester is similar to the station arrester represented in Fig. 11, except that it is conveniently mounted in an iron box.

When the pure non-arcing metals are used, the dischargers are considerably burned by the arc, for instance, here is pure antimony, which you will notice is somewhat melted away. It is the same with this sample of cadmium, which you will also notice is somewhat burned. The addition, however, of 50 per cent. of copper seems to give toughness to the metal or some similar property which does not permit the arc to burr or burn, and yet there is still a sufficient quantity of non-arcing metal present to prevent the maintenance of the arc. In commercial brass rod

there is about 35 per cent. of zinc and 64 per cent. of copper, also a small quantity of lead. I made a set of non-arcing dischargers consisting of about 50 per cent. of zinc and 50 per cent. of copper, but could not notice any perceptible difference between this and the commercial brass rod; 90 per cent. zinc and 10 per cent. copper burred very much like the pure zinc, and 90 per cent. copper with 10 per cent. zinc failed to interrupt a thousand volt short-circuit.

Here are some non-arcing metal dischargers enclosed in a small wooden box. If you will examine this box you will notice that there is not the sign of an arc on the cover or sides. There is no blackening.

Mr. E. T. Birdsall:—In that part of Mr. Wurts's paper where he speaks of the belt and the second parallel wire, he makes the remark that it is a very good lightning arrester, and also in another part of the paper he says that all we would need for a perfect arrester would be a line which was bristling with points to conduct the current to the ground. In this connection I would like to say, as a matter of history and record, that four and five years ago, in all the specifications for line work for outside pole lines which were gotten up by the old Edison Electric Light Company, we always included barbed iron fence wire; this was run along on the poles the whole length of the pole line and grounded at every two or three poles. Here we had the parallel wire bristling with points and also connected with the ground at frequent intervals. It made as far as I know a good lightning arrester, as I do not remember of any station that was struck where this plan was used, but as soon as somebody with influence in the company got out something else, we had to use that.

Mr. M. C. Sullivan:—I note that Mr. Wurts cites cases where the arc is reliable to hold on, and when this is so there is more or less fusion. I would like to ask Mr. Wurts how different this effect appears in the non-arcing from what would be considered arcing metals or the different bars he uses.

Mr. Wurts:—In experimenting with these non-arcing metal bars, I have not been able to re-establish the arc rapidly enough to raise their temperature. It is only when I use an insufficient number of air-gaps to interrupt the short-circuit and thus allow the arcs to be maintained, that the metal bars become heated. In repeatedly short-circuiting a thousand volt generator through the arrester illustrated in Fig. 11, the metal bars did not apparently change their temperature. The circuit is interrupted so instantaneously that there is no time for heating. I mentioned the heating in connection with circumstances where the arc was maintained. that is, where I used a current of higher electromotive force than could be interrupted by the number of air-gaps under test.

Mr. E. P. Thompson:—When one bar is arcing and the other non-arcing, it might be impossible to determine just what would

take place, by theoretical consideration. Have you tested this feature?

MR. WURTS:—In connection with that point I have only made this one test, namely to insert a carbon bar in between two non-arcing metal bars; but when the short-circuit was once established the arc held on most persistently.

THE CHAIRMAN:—If there is any one thing more instructive than another in what has been brought before us this evening, it is the exhaustive way Mr. Wurts has prosecuted his experiments. Whenever any gentleman has asked a question, Mr. Wurts has had his answer ready—an experiment to describe, and a sample to show.

MR. A. E. KENNELLY:—While I think it is impossible to doubt that these experiments are very novel and interesting, perhaps the most interesting of all is that one which has been elicited in discussion where a short-circuit fuse has failed to arc when shunted by a series of these air-gaps. I would like to ask Mr. Wurts whether in any of the experiments of that nature that he conducted, the electrical pressure which he used on that fuse, or the pressure of the generator which he short-circuited, was, so far as he knows, less than the pressure which would have independently forced its passage across the air-gaps that were in shunt, because if so, it would seem to indicate that the bursting of the safety catch had either raised the pressure above that of the generator, or else that it had produced locally some very unusual effect.

MR. WURTS:—Using this fuse block with the seven non-arcing metal bars arranged in a semi-circle, I connected the terminals to a 2000 volt generator, having first raised the E.M.F. to 2700 volts. That E.M.F., if I am understanding the question, would not strike an arc across these six air-spaces; but had I used ordinary metal for these bars, and once established the arc across the air-spaces, then the arc would have been maintained. It is a very different thing to establish an arc by external means, and to cause an arc to establish itself. In the non-arcing metal arrester described, the air-gaps are always sufficient to prevent the dynamo from starting an arc by its own E. M. F.

MR. KENNELLY:—Then, if I understand Mr. Wurts, had those bars been ordinary metal, say copper, the same pressure would have started an arc across the air-gap?

MR. WURTS:—No, it would not have started an arc, but it would have maintained the arc when started.

MR. KENNELLY:—I think that is a very remarkable fact and one which calls for further explanation, an explanation that does not appear to be immediately upon the surface. That is a point that I confess I am unable to understand for the moment, and it is not the only point in the paper that I have been unable to understand. But there has been one case mentioned by Mr. Wurts which I would like to have a little further elucidation upon, and that is not in connection with the particular metal which he had

employed so successfully. I think I could explain my meaning best on the blackboard. The very interesting experimental case is mentioned by Mr. Wurts in which he actually grounds a line along which power is being delivered at every pulsation of the dynamo, and right at the neutral point, or immediately before the neutral point he grounds the line. But I have not understood the exact method of protection which Mr. Wurts expects to obtain by that device, however interesting it may be in itself. We will take the case of an electrified cloud floating above the earth's surface. The pressure in the cloud may be enormously high. Let us suppose it to be a million volts, for want of better knowledge; and then suppose that we have a wire which is connected with a ground, either by direct communication, in the manner suggested by Mr. Wurts, at each pulsation, or by gradual leakage, or in any other way that you please This cloud, let us suppose, is negatively charged at a very high pressure, and then the wire will become positively charged and its original neutral charge will have been decomposed, the negative electricity will have passed into the ground, will have gone beyond the limits of this cloud, and the whole region here will be positively charged, not only the wire but all the surface of the earth in this vicinity. Now that would be the condition of affairs prior to the lightning flash. There will be a static strain all across this insulator, and there will be a positive charge, but one which is not evident, owing to the opposite influence of this negative electrification. Now suppose that a lightning discharge takes place at some point. There will now be an enormous development of apparent electrification, and that will constitute a "return stroke," or lightning stroke on a minor scale. It will not have the same power that a lightning stroke delivered here would have. But it may have a powerful local effect, and will depend for its suddenness on the suddenness of the lightning discharge. Now if this is measured in millionths of a second, the secondary electrification will be up and over in the same interval of time. But the momentary grounding of the circuit through the dynamo can only take place at definite intervals, let us say in two or three per cent. of the total time; and if the lightning discharge occupies only one or two millionths of a second, it seems to me that this device will be inoperative; but if the discharge should happen at the exact moment when the line is grounded, then of course it is possible that this might carry away the discharge. If, however, I have not understood the action of the device I desire to be enlightened.

MR. WURTS:—I think you fully understand the action of the device, but I believe I began my description of it with these words, "with the idea of gradual charging in mind." From my experiments with charged wires I had conceived the idea that possibly electric lines were gradually charged up to a high potential and not suddenly, as you have there described upon the blackboard. I am rather inclined to think, however, that they

are often charged suddenly; but may it not be that although the primary cause of the charge is sudden, the time of wave propagation is considerable; for example, if I have my neutral point arrester connected at one end of a line and suddenly have a charge induced at the other end, may not the time of wave propogation from one end of the line to the other be considerable and by grounding the far end of the line at rapidly recurring intervals, may it not be possible to help matters considerably? I do not think we can have too many lightning arresters, or too many different kinds of lightning arresters connected to the line. I would recommend an overhead grounded wire, a leakage arrester such as I have described and called a "tank arrester," also some reliable type of discharge-gap arrester in the station and at frequent intervals along the line. I know of a case where a dynamo tender, wishing to determine the best lightning arrester on the market, procured four or five different kinds and connected them to the line in parallel. When the first discharge occurred, every lightning arrester operated at the same time. And this suggests a question which I would like to ask. I would like to know if anybody has noticed, when several lightning arresters are connected in parallel and fairly close together, say, three or four feet apart, whether the charge will ever skip one of these discharge circuits and apparently make a selection. I have noticed this repeatedly, and know of a case where there are about twenty lightning arresters on one switch-board all connected to the same ground wire, and one of which has never been known to take a discharge. The air-gaps in the arresters are all one-sixteenth of an inch, and in fact all the connections and surrounding conditions seem to be the same for each arrester except that of position. It occurred to me then that perhaps the failure of this one arrester might be due to nodal points.

My question then is: Are there nodes formed by the line discharge such that it is possible to connect an arrester to a nodal point on the line, in which case there would, of course, be no tendency to discharge?

MR. LOCKWOOD:—Although the subject is perhaps, from the telephone and telegraph man's point of view, rather an overestimated one, if I may judge by the remark with which Mr. Wurts turned off the subject on the first page—"The spark gap arrester on telegraph lines answer the purpose admirably"—still I think I will venture a word or two on that part of the subject. As I understand the paper, the first part of it addressed itself largely to lightning arresters *per se*, without regard to whether the generators exciting the circuit were alternators or continuous current generators, while the latter part, in which the non-arcing metals were described, related more particularly to alternating circuits. Now, as Mr. Prescott very pertinently observed, there has been a great deal said about lightning arresters, and I think he meant there has been a great deal said which might just as

well have been left unsaid. It is one of those things which nearly every electrician from 1840 down, has felt himself at liberty to theorize about, and I do not know that the habit has quite left the race. While speaking of theories I should like to say that the theory which the speaker of the evening has developed concerning the reason that some metals under an alternating electromotive force of very high voltage, will not arc while others will, seems to me to be at least a plausible one. We know now that the useful arc which is displayed between the carbon points of an electric arc lamp is produced first by a spark, and then by the extremely hot vapor, carbon vapor which exists between the points, and I do not think it is very unfair reasoning to say that inasmuch as a conducting vapor will maintain an arc, that a non-conducting vapor won't.

In a work on telegraphy, called the Telegraph Manual, by Taliaferro P. Shaffner, which was published in New York in 1859, there is a very good chapter on lightning arresters, at pages 564 and 586, and the first time I read that chapter I was very much interested to observe that the spark gap arrester which answers the purpose so admirably for telegraph work, even so far back as 1859 and before that, was not considered on the French railway lines and by French railway electricians to be "all that was required," and a very good picture is found there of not only the saw-tooth air gap, but closely associated therewith is a long wire evidently intended to be fused and to open the circuit. Such a combination has, to my certain knowledge, been attempted at least to be patented some half dozen times in the last half a dozen years, but I do not know whether that has been cited as a reference to any of them. Shortly after the telegraph was industrially started in this country by Mr. Morse, a gentleman whom many of us know personally, Mr. J. D. Reid, whom we are in the habit sometimes of calling the nestor of telegraphy, invented the first electro-magnetic "lightning protector," as he called it, although I never could see why lightning needed any protection—like a good many other things we protect in this country. Perhaps "apparatus protector" would have been a better name. It consisted of a very coarse wire magnet, provided with an armature and a pivoted lever; a strong counteracting spring pulled one end of this lever over to one side, and held the lever which was in contact with the line against a contact leading to the instrument (the circuit coming first to the magnet, then to the lever, then from a platinum point on the lever to the contact post which led through the instrument to be protected, thence either to earth or to the next station.) There was a ground post just under the other end of the lever, and an air-gap of about one-eighth of an inch between the lever point and the ground post, and the idea was that when the lightning discharge came, this magnet would be energized, and would pull away temporarily the armature from the old position against the

force of the counter-spring, and would discharge it to earth and then the counter-spring would at once pull it back, and in this same Shaffner's Manual there is a picture showing the very experiment which the protective apparatus enthusiast always shows, to prove how successful and efficient his protector is. That is, there were a couple of pieces of fine copper wire which were to be saved, and in the experiment which Mr. Reid carried out they were saved; and his machine was considered in its day such an important device, that the Franklin Institute gave its silver medal to Mr. Reid for the meritorious invention. But he very soon found out that it was not necessary, and as he has himself said, he found out that a very much better protector was to put a lightning rod on each pole, and run this wire we have heard about this evening from pole to pole, grounding it where necessary on the pole rods. This expedient has been used in this country and England for a great many years. But in telephony, although the telephonic current is, speaking from the point of view of strength, the weaker vessel, it perhaps makes up for the slenderness of its current, by the number of telephone lines there are in the United States compared with other electrical wires. If it was only lightning that telephone apparatus had to be protected from, there would not be much trouble in protecting it successfully and easily. When Mr. Sargent, whom many of you know very well, and who is General Manager of the telephone company in Brooklyn, was in Philadelphia, so little was he troubled by lightning that he never found it necessary to put a lightning arrester on any line whatever, and he never had any instrument destroyed by lightning. Since, however, the advent of the arc light with its 30 to 40 or 50 lamps upon a circuit, and since the second advent, if I may so call it, of the electric railway, the telephone has not possessed a complete immunity from destructive influences; and one of the worst troubles about contacts between telephone lines and lines carrying heavy currents is this very tendency—a discharge once having passed—for a perpetuation of the arc which we have heard about this evening, which tendency has been found in larger electrical installations to be so destructive; and therefore telephone men have found it necessary now not only to put on air-gaps to discharge dangerous potentials - and this with metallic circuits I should say—they have also found it necessary to put on something, and preferably a thermal protector, which will first break the circuit and then either ground it or short-circuit it, so as to avert the dangerous results of what we have learned to call "sneak currents," for we have found in our business where we have so many wires massed together, that it is not the very heaviest currents which are the most dangerous, but those which creep in and smolder in the insulation for some time and finally break out into a blaze, after the smoldering has gone so far that when the blaze breaks out it is almost impossible to save anything within a radius of perhaps two hundred feet.

The third form of dangerous current we have to protect ourselves against, is that which comes on in values of from five amperes upwards, which is not a sneak current by any means but which makes its onslaught boldly. However, as I have said, the sneak current we have found the most dangerous, all things considered, and during the last three or four years a great many devices have been invented to circumvent it. One very interesting one which has recently been called to my notice was gotten up in Colorado. It consists of a little box of hard rubber with a cylindrical perforation through it, closed by a hard rubber plug on the lower side. There is a chamber of about three-quarters of an inch long and from half an inch to five eighths of an inch in diameter in the centre of this plug, and within the chamber is coiled up about twenty-five feet of very fine german silver covered, wire. While its resistance considered by itself is not great, still on a heating current coming on, the resistance of the circuit is pretty well concentrated into that little chamber; a great portion of the heat at all events is so concentrated. Through a small pin hole in the upper part of the rubber box are dropped a couple of globules of mercury, which of course penetrates into the chamber and gets all around this little coil of wire. The pin hole is then covered up with a very thin membrane of say thin sheet rubber, which is cemented down by bicycle tire cement, or some similar substance so that the aperture is perfectly light. Fixed to the metal post on one side and having one end in contact with the line circuit, is a thin spring which carries at its front end a contact point and which lies at its free end in contact or right on the top of this thin rubber membrane. Immediately above the contact point is an earth contact, or a contact which may lead to the other side of the curcuit in the case of a metallic circuit. In addition to this, there is a fuse which perhaps will disappear with a current of four, five, six or seven amperes. After passing through the fine wire the circuit leads to the instrument. When a dangerous current comes in, it heats up this fine wire coil, and causes the mercury to expand, and if the heat goes on, it causes the mercury to vaporize. The rubber sheet is bulged out and presses the free end of the contact spring against the rough points, short-circuits the circuit, cuts the instrument out and either blows out the fuse or works like a vibrating contact. It short-circuits the fine wire coil, I should also say, at the same time. The heat goes down, the mercury condenses and the rubber sheet contracts.

I would like before sitting down to express the great pleasure I have experienced in hearing the paper of the evening and especially in listening to the very prompt and instructive way in which every question has been answered, by Mr. Wurts.

THE SECRETARY:—Mr. Wurts, who is with us this evening and who has presented this paper, has not yet become a member of Institute, but his application is in, and if it had been a little

earlier it would have been favorably acted upon. I desire before we close to offer a vote of thanks to him, for the care and trouble he has taken to prepare this paper and bring it before us in such good shape, and also in having given it to the Secretary in time to have it printed in advance.

[The motion was carried.]

THE SECRETARY:—At the February meeting of the Council, it was decided to hold the General Meeting this year in Chicago. It has not been the usual practice of the Institute to hold its general meetings outside of New York City, but two years ago a meeting was held in Boston, and the Council has felt that the time has now come when we can obtain a sufficient attendance in any city that we may care to visit, to hold a successful meeting. At the Council meeting to-day it was decided to hold that meeting in Chicago on Monday and Tuesday, the 6th and 7th days of June. The Annual Meeting for the election of officers and the reception of yearly reports, and the transaction of business will be held in this house on the third Tuesday in May; that is fixed by the rules. This meeting has heretofore been held in conjunction with the General Meeting, but this year it has been thought wise to postpone the General Meeting a little later, and it is also proposed in connection with the Annual Meeting in this city to have a dinner. The meeting will convene at about four o'clock in the afternoon and adjourn for dinner at 7 o'clock. It has been felt by a good many that it has been some time since we got together in a social way, and that this would be a fitting occasion for such an event.

At the Council meeting this afternoon, the following Associate Members were elected.

Name.	Address.	Endorsed by
ALDRICH, WILLIAM S.,	Associate in Mechanical Engineering in the Department of Electrical Engineering, Johns Hopkins University, Baltimore, Md.	Louis Duncan. C. T. Hutchinson. H. S. Hering.
BLAKENEY, W. H.,	Firm of Blakeney and Rennie, Mechanical and Electrical Engineers, 33 Bath St., Glasgow, Scotland.	Geo. M. Phelps. Francis R. Upton. Ralph W. Pope.
CARROLL, DWIGHT F.,	Instructor in Electrical Engineering, Lehigh University, South Bethlehem, Pa.	R. O. Heinrich. Ralph W. Pope. T. C. Martin.
LENZ, CHARLES OTTO,	Draughtsman (Electrical), Edison General Electric Co., Box 3067, New York City.	J. H. Vail. Charles Hewitt. Robert T. Lozier. J. Stanford Brown.
MARTIN, A. J.	General Supt., West End Electric Co., 1310 N. 29th St., Philadelphia, Pa.	H. A. Reed. G. A. Hamilton. H. A. Foster.
PEROT, L. KNOWLES,	Consulting Electrical Engineer, 308 Walnut St., Philadelphia, Pa.	H. G. Reist. J. B. Cahoon. Franklin Sheble.

SACHS, JOSEPH,	Electrician. The American Engineering Co., 109 World Building; residence. 1839 Lexington Ave., New York City.	Joseph Wetzler. T. C. Martin. Ralph W. Pope.
WESSELS, EDWARD J.,	New York Agent, The Short Electric Railway Co., 121 World Building, New York City.	E. P. Thompson. Edw. E. Higgins T. C. Martin.

Total, 8.

The following named gentlemen were transferred from Associate to Full Membership:

AYRES, BROWN	Professor of Physics and Electrical Engineering, Tulane University, New Orleans, La.
ROBB, WM. LISPENARD	Professor of Physics, Trinity College, Hartford, Conn.
UPTON, FRANCIS R.	Treasurer and General Manager, Edison General Electric Co., Lamp Works, Harrison, N. J.

Total, 3.

[Adjourned]

Standing Committees appointed by direction of Council:

Editing and Library Committee.

GEORGE A. HAMILTON, } Editing. JO. STANFORD BROWN, } Library.
FRANKLIN L. POPE, } Editing. GEORGES D'INTREVILLE, } Library.
FRANCIS B. CROCKER. GEORGE H. STOCKBRIDGE. }

Committee on Membership, etc.

RALPH W. POPE, Chairman.
THOMAS D. LOCKWOOD, Local Secretary, Boston, Mass.,
DR. LOUIS DUNCAN, " " Baltimore, Md.,
CARL HERING, " " Philadelphia, Pa.,
PROF. EDWARD L. NICHOLS, " " Ithaca, N. Y.,
PROF. W. A. ANTHONY, " " Manchester, Ct.
JOSEPH WETZLER, New York.
GEO. B. PRESCOTT, Jr., New York.

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GEORGE M. PHELPS, Chairman.
GEORGE A. HAMILTON, DR. SCHUYLER S. WHEELER, THOMAS A. EDISON, FRANKLIN L. POPE, FRANCIS R. UPTON, T. COMMERFORD MARTIN, DR. F. BENEDICT HERZOG.

Committee on Papers and Meetings.

T. C. MARTIN, Chairman, GEORGE M. PHELPS, JOHN W. HOWELL, HUBERT HOWSON, DR. SCHUYLER S. WHEELER, HERBERT LAWS WEBB, H. WARD LEONARD, PROF. FRANCIS B. CROCKER.

Committee on Units and Standards.

A. E. KENNELLY, Chairman, GEO. B. PRESCOTT, Jr., GEO. A. HAMILTON, DR. WM. E. GEYER, FRANCIS B. CROCKER.

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[Complete sets of the first four volumes are out of print.]

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SPECIAL NOTICE.

The Annual Meeting for the election of officers, the reception of yearly reports, and the transaction of business, will be held at the headquarters of the Institute in New York City, on Tuesday, May 17th, and will be followed by a dinner in the evening at the "Arena," 30 and 41 West 32st street. The General Meeting for the reading and discussion of papers will be held at Chicago, on Monday and Tuesday, June 6th and 7th. The headquarters of the Institute during this meeting will be at the Grand Pacific Hotel. The programme of papers is now in preparation.

COMMITTEE OF ARRANGEMENTS AT CHICAGO.

E. M. Barton, Chairman, C. A. Brown, Dr. Elisha Gray, W. A. Kreidler, Charles Wirt.